Dynamic Revenue Analysis in California, An Overview

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Introduction

There has been an ongoing debate at the national level about the wisdom of incorporating the dynamic effects of economic agents when estimating the revenue impact of tax changes. This debate has been sharpened with the introduction of resolutions (Rep. Tom Campbell and Sen. John Ashcroft) requiring federal agencies to prepare dynamic revenue analyses under certain conditions. While that debate has been interesting to economists and state revenue estimators, it was rendered moot in California with the passage of SB1837 in August, 1994.

This legislation requires the Legislative Analyst's Office (LAO) and the Department of Finance (DOF) to incorporate the effects of the dynamic responses of economic agents when evaluating the impact of revenue proposals. This legislation initiated a development process that has now come to fruition. An economic model has been built; is being used by DOF staff when analyzing revenue proposals for the Administration and the Legislature; and is being revised and enhanced to keep its data current and to improve its content.

This paper is offered to help other state revenue-analysis staff who may be faced with requirements or requests to perform such analyses. Each state faces its own institutional needs and economic conditions. However our experience may help other states to avoid 're-inventing the wheel.'

The plan of this paper is to introduce the subject of dynamic revenue analysis, *i.e.* establish the motivation for doing such work. The alternative approaches available are considered to assist readers with understanding our choice of model style. Incorporated is a general description of Computable General Equilibrium models and some of the general aspects of the model built for California. This is followed by a discussion about what makes a regional economy different from its nation's—issues ignored at the peril of producing unrealistic results that would be difficult to defend. Finally, a general discussion of the model's development and some preliminary results are presented.

Background

In August 1994, legislation (Chapter 383, Statutes of 1994) was enacted requiring DOF to provide dynamic analysis of all revenue bills with a static revenue impact of $10 million or more. LAO is required to perform similar analysis of revenue proposals included in the Governor's Budget.

DOF and LAO conducted initial examinations of the techniques available to perform dynamic analysis. Following initial investigations, DOF commissioned a formal review of the economic literature relating to dynamic analysis, which was conducted by Peter Berck of the Agricultural and Resource Economics (ARE) Department at the University of California, Berkeley (Berck and Dabalen, 1995). The survey concluded that a computable general equilibrium (CGE) model was the most appropriate analytical method to comply with the requirements of SB 1837.

LAO surveyed other state governments and found that few had made any significant attempt at dynamic analysis. Massachusetts was a notable exception. However their effort, led by an outside consultant and involving the purchase of an "off-the-shelf" model, ran into difficulties. We have been told that it is presently being redeveloped.

Partly as a result of Massachusetts' experience and as an outgrowth of the preliminary research, the DOF determined that its analytical responsibilities would be carried out:

- within the Department by its own staff, who would have full knowledge of the workings and behavioral properties of any model employed in analysis; and
- using modeling techniques most appropriate to the task.

In September of 1995 DOF hired additional staff and contracted with ARE to help construct a CGE model of California. The following is adapted almost entirely from the report describing the model: *Dynamic Revenue Analysis for California* (Berck *et. al.*, 1996).

Dynamic Revenue Analysis

Dynamic revenue analysis is one of three approaches to analyzing the effects on a state's revenues of new bills being considered. Static and behavioral are the other two.

An example of a purely static analysis would be a prediction that a new tax of 10 percent on a product with $1,000,000 of sales would generate a $100,000 increase in revenue. A more extended analysis may predict a smaller revenue gain because the tax would lead consumers to buy less of that product. This more extended analysis is often

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called behavioral because the behavior of economic agents (households or firms) directly affected by the tax is considered.

In dynamic revenue analysis, the exploration into economic behavior continues further through the economy. Behavioral changes of agents affect the decisions of other agents. Using our example, the introduction of the tax leads consumers to buy less of the taxed product (and, perhaps more of other products). As a result, firms producing the taxed product produce less and employ fewer people. Those people who lose jobs have lower incomes and consume less, thereby reducing the demand for all goods.

Firms with lower accounting profits would pay less corporate income tax. The laid-off employees not only do not pay taxes but also may become eligible to receive social benefits. The state loses tax revenue from these effects, and its expenditures may increase. However, some or all of this may be offset by the state purchasing additional goods from its increased tax revenues. Further effects are felt throughout the economy, some so subtle as to be extremely difficult to describe in an overview such as this.

To develop an analytical engine with which to examine the revenue implications of the dynamic responses of economic agents, a major research program was required. The main tasks in building the California Dynamic Revenue Analysis Model (DRAM) were to:

- Choose a modeling style appropriate to the task at hand;
- Find data of both national and California-specific character;
- Define the aggregates to be used in the model;
- Review the literature on the functional forms and elasticities for the primary behavioral equations in the model (such as: consumption, production, trade, investment, labor supply and migration);
- Assemble the data and equations into a working model; and
- Calibrate the model to current economic conditions and test the assumptions and parameters of the model by means of sensitivity testing.

Choice of Modeling Style

Regional economies have been modeled for public policy analysis using a variety of model styles which can be grouped into four styles: input-output; micro-simulation; econometric simulation; and computable general equilibrium models. Very briefly, each of these will be discussed in terms of a general description of each model's structure, along with an indication of the types of policy issues for which they are most appropriate.

Input-Output Models

These remain the most common type of regional economic model—especially for studies of the impact of local (sub-state regions) policy actions such as infrastructure changes, industrial location subsidies or changes in local property taxes. Input-output models are based on a matrix in which the payments from a sector are apportioned in fixed shares to the purchase of intermediate goods (used up in production), factors (such as labor and capital), taxes and imports. Other columns represent the fixed shares of consumption and savings by households, governments and investment activities.

The data for these models are available in easily manipulated form, such as IMPLAN, in which a roughly 3-digit SIC code aggregation is possible. Further, there is a well-established body of literature and little disagreement among practitioners of this form of analysis. Finally, there is an appealing simplicity to the mathematical manipulation required—even when one considers highly disaggregated economic models of one or many regions. Simple linear algebra can usually generate a closed form solution with policy multipliers. Of course, these multipliers depend on the parameters and structure of the model remaining constant—often including constant prices.

Although an input-output model may be useful for establishing the extreme outer bounds of short-term fluctuations in local regions, this model style's linearity—when combined with fixed prices and little or no substitution—guides one to accept this style of approach as being far closer to a purely static analysis—lacking most of the behavioral aspects of consumer or firm substitution due to prices, let alone truly dynamic effects.

Micro-Simulation Models

Virtually every revenue estimation function at the federal and state levels and even in many such functions at local governments maintain one or more such models. Generally these have been built at the federal and state level from samples of actual taxpayer returns for corporate profits and personal income taxes and they may or may not include econometrically estimated equations for behavioral changes from past tax policy changes.

In California, we are fortunate to have available an excellent micro-simulation model for state personal income taxes, a model built and maintained by the Franchise Tax Board. It has been used to enhance the purely static analyses of personal income tax policy changes. However, the following wording generally appended to their fiscal analysis reveals why this type of model is a very good complement to, but not substitute for, dynamic analysis: "..., this estimate does not account for changes in employment, personal income, or gross state product that might result from this measure."

At the heart of the search for acceptable methods with which to incorporate the dynamic response of economic agents in revenue analysis are the overall economic conditions. Thus, micro-simulation techniques became a part of the later choice of model style.

Econometric Simulation Models

These models may best be described by what many consider its best example: Regional Economic Models Inc. (REMI), although many other examples exist. In REMI, equations describing the economy of a region are estimated subject to two sets of external influences: exogenous variables (such as exchange rates and interest rates) and input-output shares for intermediate goods (any good used up in producing other goods, such as fertilizer used in agriculture). The imbedding of an input-output table to calculate the demand for intermediates assures that evolving levels of demand for final goods will have a reasonable (although fixed in shares) distribution of demands for goods used up in production.

REMI is a particularly interestim model, with 53 industries, 94 occupations, 25 final demand goods and 202 age-sex cohorts. REMI would be very useful for profiling a regional economy, but its use for dynamic revenue analysis is problematic for two main reasons:

- since the critique of Dr. Lucas (1976), a structural model would have exposed our results to major criticism and possible outright rejection by most economists had we chosen this style; and
- prices do not clear markets in this model type—*i.e.* the internal structure of the model has limited explicit representation of core economic theory, especially the microeconomic theory of utility and profit maximization.

While this type of model was not our choice for dynamic revenue analysis, it would be useful in situations in which price signals were considerably less important than in major tax changes. Rather than using input-output analyses, the use of complex regional econometric simulation models would be likely to produce better predictions for small, localized policy changes.

Computable General Equilibrium Models

These are the most recent contribution to applied economic modeling. While their mathematical details were laid out almost completely in the 19th Century by Leon Walras (1954, the first American translation of this work), their implementation into useful (in a policy analysis sense) models awaited the development of mathematical algorithms being efficiently implemented into computer software running on increasingly inexpensive computers. Without all three of these developments, only simple and highly aggregated models were possible.

In this section, we assume that readers have little knowledge of Computable General Equilibrium (CGE) models and begin by describing these. During the course of this description, it will be apparent why this style of model was chosen for dynamic revenue analysis.

Dynamic analysis of the effects of California taxation requires a comprehensive model of the California economy. The model needs to track income of individuals and firms, since this is the basis for income taxation. It needs to track sales of goods and services, since these are the bases of sales, excise, and insurance taxes. However, to be dynamic, it needs to do more than that. It must account for the effects of taxation on the economy's use of labor and capital and many other economic reactions.

A computable general equilibrium model is a model that does all of these according to the basic economic principle that quantity supplied is equal to quantity demanded at a particular set of prices in all markets. It is called "computable" because, rather than calculating general algebraic solutions, specific numeric solutions are found to questions posed to the model. It is called "general" because all markets and all income flows are included in the model. Further, it is called an "equilibrium" model because prices in the model adjust to make the quantities demanded for and supplied of goods, services, and factors of production (labor and capital) equal.

A CGE model is a description of the relationship among producers, households, government and the rest of the world. The model cannot include an accounting of every individual producer, household, or government agency in the economy. To provide focus to the model, agents must be aggregated into sectors.

Aggregation: DRAM treats aggregates rather than individual agents. This is done both to provide focus for the analysis and to contain the number of variables in the model. A correct aggregation or sectoring is an important element in the development of any CGE model because it determines the flows that the model will be able to trace explicitly. For the DRAM model, the California economy has been divided into 75 distinct sectors: 28 industrial sectors, two factor sectors (labor and capital), seven household sectors, one investment sector, 36 government sectors, and one sector that represents the rest of the world.

Data for the industrial sectors originated with the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce, based on the Census of Business — a detailed survey of companies conducted in the United States every five years. In this survey, information is gathered about the purchases of intermediate goods, payments to factors (labor, capital, land, and entrepreneurship), and taxes. Although the survey is quite extensive, it yields only enough detail to be able to make inferences about groups of firms at the national level.

In addition, the most recent survey available was made in 1987. The conversion of national data to updated California data is accomplished by Impact Analysis for Planning (IMPLAN), a program which primarily utilizes state-level employment data to scale national-level industrial data down to the size of a state. To arrive at more current output levels, estimates were obtained from the DOF's econometric model of the state for an industrial breakdown fitting our model as closely as possible. These were combined with IMPLAN data to arrive at a reasonable approximation of 1995/96 expected economic conditions.

In much the same way, households are aggregated. California households were divided into categories based upon their taxable income. There are seven such categories in the model, each one corresponding to a California personal income tax marginal tax rate (0, 1, 2, 4, 6, 8, and 9.3 percent). Thus, the income from all households in the one-percent bracket is added together and becomes the income for the "one-percent" household.

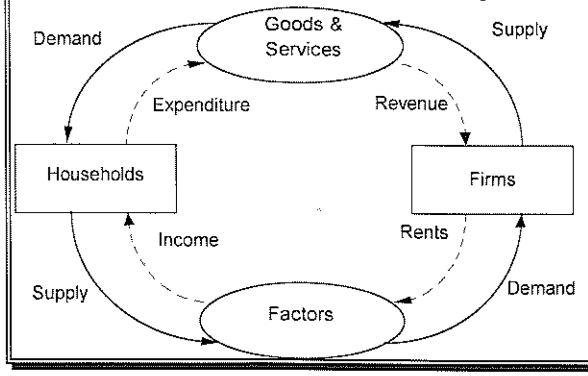
Similarly, all expenditure on agricultural goods for these households is added and becomes the expenditure of the one-percent household on agricultural goods. The total expenditure on agricultural goods is found by adding the expenditures of all households together. Data for income come from the Franchise Tax Board personal income tax "sanitized" sample, while data on consumption by income come from a national survey (Consumer Expenditure Survey).

The government sectors in DRAM are organized so that important government revenue flows and expenditure flows can be traced explicitly. The DRAM includes 36 government sectors: seven federal, 21 state, and eight local. Data for the government sectors come from published federal, state, and local government reports.

Final Demand and Factor Markets: The beginning point for the description of the California economy and, hence, the California CGE model is the relationship of the two major types of agents: producers and households. Producers, also known as firms, are represented in the model as aggregates or sectors, where each sector is treated as a representative firm. Each of these sectors or producers treats the prices that it sells its product (for example, agricultural products) and the prices that it pays for its inputs (capital and labor, called "factors of production," and other inputs, called "intermediate goods") as fixed. This is the assumption of competition.

The producers do not believe that their decisions have an effect on prices. Each producer is assumed to choose inputs and output to maximize profits. Inputs are labor, capital, and intermediate goods (outputs of other firms). Thus, the producer's supply of output is a function of price and the producer's demand for inputs is a function of price.

Figure 1: The Basic Circular Flow Diagram



Households make two types of decisions. They decide to buy goods and services. They decide to rent labor and capital to firms. They are assumed to make these decisions in the way that maximizes their happiness (called "utility" in economic theory). Like firms, they take the prices of the goods that they buy and the wage of the labor and rental rate of capital that they rent as fixed. Their supply of labor, as a function of the wage rate, is called the "labor supply function." Their supply of capital, as a function of the return to capital is called the "capital supply function." Their demand for goods or services, as functions of prices, are called the "demand functions." In addition to their labor income, households receive dividends and interest from their stocks and bonds and other ownership interests in capital.

Equilibrium: Thus far, two types of agents have been described: firms and households. It remains to be explained how these agents relate. They relate through two types of markets: factor markets and goods-and-services markets. Firms sell goods and services to households on the goods and services markets. Households rent labor and capital services to firms on the factor markets. There is a price in each of these markets. There is a price for the output of each of the 28 sectors. There is a price for labor, called the "wage rate," and a price for capital services, called the "rental rate of capital."

Equilibrium in a market means that the quantity supplied (which is a function of price) is equal to the quantity demanded (also a function of price) in that market. Equilibrium in the factor markets for labor and capital and in the goods-and-services markets for goods and services defines a simple general equilibrium system. That is, there are 30 market-clearing prices (the wage rate, the rental rate of capital, and one for each of the 28 goods made by the 28 sectors) and these 30 prices have the property that they equate quantities supplied and demanded in all 30 markets. These relationships are shown in more detail in Figure 1: The Basic Circular Flow Diagram.

In this figure, the outer set of flows, shown as solid lines, are the flows of "real" items, goods, services, labor, and capital. The inner set of flows, shown as broken lines, are the monetary flows. Thus, firms supply goods and services to the goods-and-services market in return for revenues that they receive from the goods-and-services markets. Firms demand capital and labor from the factor markets and in return pay wages and rents to the factor markets. Their motivation to demand factors is that they are required to make the goods that can be sold for profit.

Households, the other type of agent in a simple model, demand goods and services from the goods-and-services markets and give up their expenditure as compensation. They sell capital and labor services on the factor markets and receive income in exchange. Their motivation to supply factors is to gain the income that allows them to buy goods, the consumption of which adds to household utility.

Intermediate Goods: The economy of is far more complex than that shown in Figure 1. There are not only final goods and services markets, but also intermediate goods markets in which firms sell to firms. A typical example of this would be chemicals sold to agricultural firms. The final output of the chemical industry (perhaps fertilizer) is said to be an intermediate good in the agricultural industry. This type of market is demonstrated in Figure 2.

The expense of buying the input is a cost of production. The motivation of firms supplying intermediate goods is simple: the revenue gained creates the potential for profits. The motivation of firms demanding intermediate goods is equally simple: the goods are needed to make other goods that can be sold for profit.

Here, part of the supply of a firm (the chemical industry in the example) is not sold to households but rather to another firm in exchange for revenue. From the other firm's point of view, it buys an input to production from a firm rather than from a household.

Rest of the World: California is an open economy, which means that it trades goods, services, labor, and capital readily with neighboring states and countries. In this model, all agents outside California are modeled in one group called "Rest of World." No distinction is made between the rest of the US and foreign countries. California interacts with two types of agents: foreign consumers and foreign producers. Taking the producers first, the Figure 3 shows that the producers sell goods on the (final) goods and services markets and on the intermediate markets, i.e., they sell goods to both households and firms.

The model takes these goods as being imperfect substitutes for the goods made in California. Agricultural products from outside California (for example, feed grains, bananas) are taken as being close to, but not identical to, California-grown products (for example, avocados, fresh chicken). The degree to which foreign and domestic goods substitute for each other is very important. Foreign households buy California goods and services on the goods and services markets. They and foreign firms both can supply capital and labor to the California economy.

Figure 2: Circular Flow with Intermediate Goods

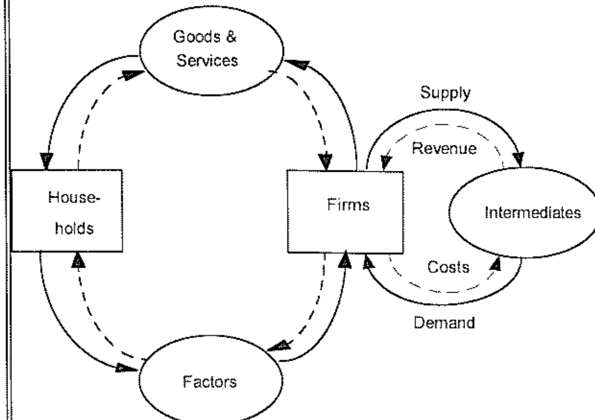
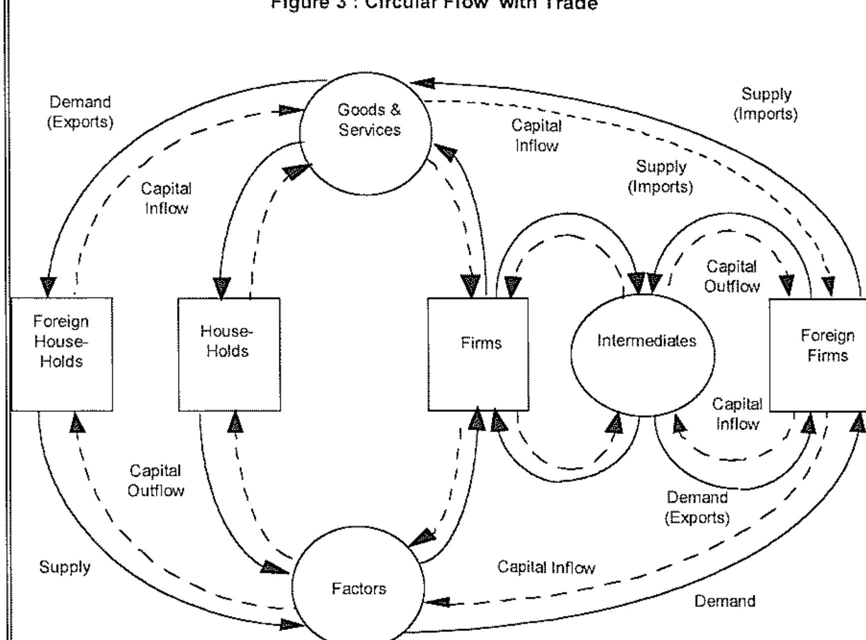
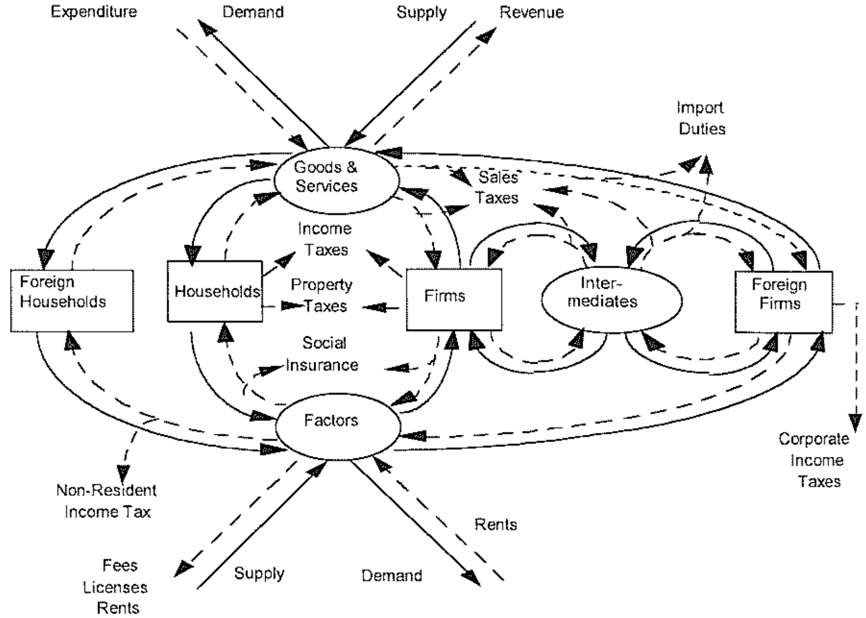


Figure 3 : Circular Flow with Trade



Government: Combining the taxing and spending effects of the three levels of government (federal, state, and local) gives the additional flows in Figure 4. Beginning at the top of Figure 4, government buys goods and services and gives up expenditure. It supplies goods and services for which it may or may not receive revenue. Government also supplies factors of production, such as roads and education. Not shown in the diagram are the transfer payments to households. The middle section of the diagram shows many of the ways in which government raises revenue through taxation.

Figure 4: The Circular Flow with Government



Differences Between a Regional and National Model

There have been hundreds of CGE models built and used for analyzing public policy at the national and international level. Regional, or sub-national, CGE models are very similar in design to national and international models, but exhibit major differences in several key aspects due to the differences between a region's economy and that of its nation:

1. Perhaps the most important difference is that regional CGE models do not require that regional savings equal regional investment. When Californians save more than California investors want to use, excess savings flow out of the state. When the converse is true, savings flow into the state. Rational economic agents would not accept less interest on their savings from California investors if higher interest rates were available in other states or countries. Conversely, rational investors in California would not pay higher interest for the use of Californian savings if other states or countries offered lower rates.

2. Regional economies trade a larger share of their output. Therefore, trade is more important in regional models. Note that interstate trade is part of the Rest of World for California, but is ignored in national considerations of trade.

3. Regional economies face larger and more volatile migration flows than nations. Regional and international migration to California is a major factor in the state's economy.

4. Regional economies have no control over monetary policy. The Federal Reserve is responsible for monetary policy and is a national institution. States do not control interest rates or exchange rates.

5. In regional models, taxes are interdependent through deductibility. Some local taxes are deductible from incomes subject to California personal income and bank and corporation taxes. Some local and state taxes are deductible from incomes subject to Federal personal income tax and may be eligible for deduction from corporate incomes for federal purposes. In DRAM, the personal tax deductibility is modeled explicitly. Since corporate deductibility is more uncertain, and since the apportionment rules may reduce the connection to federal corporate taxes, corporate deductibility has not been included in DRAM.

6. While good data for a CGE are hard to find at the national level, in many cases they are nonexistent for regional economies. The DRAM uses published economic and statistical literature to simulate much of the data important to our model. In some cases, such as labor supply, a wide variety of results is presented in the literature. This problem is addressed in three ways: values are chosen so as to avoid the extremes; the model is tested to determine the degree to which results are dependent upon our assumptions (this process is called "sensitivity analysis"); and the use of data from published literature is minimized.

7. The California CGE differs from a national CGE in that California faces a balanced-budget requirement.

Even if this is ignored in the short run, bond markets tend to reflect this fact. When California issued bonds to cover fiscal deficits in the early 1990s, bond ratings forced up the cost of borrowing. Ultimately, California could face prohibitive borrowing costs should it decide to return to this type and level of borrowing.

Model Development

A development team was established and comparative advantage was exploited to develop a useful model, fairly quickly and at a reasonable cost. Researchers at ARE (Drs. Berck and Golan, plus a graduate student) possess comparative advantage in theory and literature surveys—efforts that can be viewed as part of the fixed costs of establishing a model. DOF staff (Dr. Smith and a research analyst) possess comparative advantage in government revenue and finance data, plus the detailed implementation of the model in the mathematical programming software (General Algebraic Modeling System, or GAMS)—efforts that can be viewed both as part of the fixed costs of establishing a model and ongoing costs of maintaining and using it.

Following a general sketch of model design, team members performed individual research which was presented and discussed at biweekly meetings. Choices of aggregation, functional form, parameters and data structure and sources were made as a team and further research needs flowed from each meeting. While the major agents in the economy were identified, the relationships between these agents were specified and data were acquired, the model was built. It underwent extensive testing and peer evaluation before its results could form the basis for dynamic revenue analysis of proposed legislation.

Readers considering pursuing a path similar to the development of DRAM will need to obtain specialized software to solve their model. For the California model, the choice was to purchase GAMS and a general non-linear optimization solver (CONOPT). GAMS is a modeling program that permits one to specify a mathematical problem using a compact and transparent notation. GAMS interprets the input file, prepares input files for a solver, invokes the chosen solver, and extracts the output of the solver—allowing the user to manipulate the results in straightforward ways. The main advantages of GAMS with a general non-linear optimization solver include transparency of model specification and that a user does not need to become familiar with the various input requirements of each solver available (there are many solvers available). Its disadvantages include the need to become familiar with using GAMS and to define a well-ordered general equilibrium problem. Given that the present DRAM has about 1,100 equations grouped into about 50 types of equations, and that general equilibrium problems suffer from interrelationships between equations requiring care in the specification of closure conditions, the specification of a model is a non-trivial task.

Several alternatives exist. One could use GAMS, but incorporate a CGE-specific solver and data manipulator (MPSCGE). Users less familiar with CGE models may find such a solution preferable as they would be forced to establish a well-ordered problem, but, as with all choices in modeling, this comes at a cost. With MPSCGE, this comes at the cost of losing the relative transparency of model specification (*i.e.* the equations specified will not be in a form much like mathematical notation) and of encountering difficulties detailing the intricacies of general and special funds tax sources and destinations. Thus, ease of implementing a model may or may not be overcome by difficulty in specifying the model in terms that MPSCGE will handle. Readers are encouraged to visit the home page of GAMS (http://www.gams.com) to learn more about these choices.

A final note about dynamics: the current version of the model allows comparisons of the current taxation system with an alternative system. It is fully "dynamic" in that most responses and feedback of an economic sort are represented. It currently supports only the comparison of long-run outcomes—that is, outcomes after all migration and investment have taken place. Under development is a multi-period model in which the time path of dynamic adjustment by both private and public economic agents is modeled.

How the Model Can Be Used

First, the immediate goal of fulfilling the statutory requirement will be met. DOF staff use the model to assist in performing dynamic revenue analysis of legislation. The model does not perform this analysis but is a primary tool used to produce experimental results to supplement economic analyses of major legislation. DOF plans to limit its efforts in 1996 to bills with a static revenue estimate of $100 million or more until further model development occurs to improve the precision of the model. It is important to note that State revenues are on the order of $60 billion. $100 million represents one part in 600 of the State's revenue—a very tiny percentage.

Second, DOF plans to use DRAM as the basis for further research by the University of California at Berkeley team members and other researchers in 1996. CGE models are particularly sensitive to the design of factor markets, and the team was forced to use national data that are several years old. Research to establish California consumption, labor supply, migration, investment, and production functions may enhance the model considerably.

Third, other state governments are in the midst of developing their own forms of dynamic revenue analyses—whether in response to legislation or expectation of the need for these analyses. DOF will share its research with other states, a process that has already begun. The details of the DRAM model are available on request, and DOF hopes to gain both from the research of others and from the insight of others reviewing DRAM.

A caveat is important. CGE models have comparative advantage over other modeling methods when one analyzes the possible impact of structural change. Econometric simulation models are superior when the past is a good predictor of the future. Combining the best use of both, it seems appropriate to use a forecasting model, such as the one maintained by DOF, to set a base case and then use a policy model, such as DRAM, to project the differences from that case should particular legislation be enacted.

Sensitivity Analysis

DRAM was developed to guide the analysis of critical policy issues brought before the Governor, Senate and Assembly of the world's seventh largest economy, the State of California. The Department of Finance needed to be assured of the properties of its model before conducting dynamic revenue analysis using DRAM. One of the ways of learning the properties of a mathematical economic model is through sensitivity analysis. This process exposes a model to policy changes in order to identify its properties, the impact of key assumptions and the implications of values chosen for key parameters, many of which were imposed using professional judgment after a review of published literature. Sensitivity analysis should indicate the relative importance of these parameters.

The model was tested by examining the model solutions with different tax cuts, parameter values and rules for the government sector. Following calibration of the model (explained below), the base case set of experiments tested the model solution in response to three tax cuts, each using key elasticities chosen at their middle ground levels from the literature and assuming: Test 3 will apply to a fully endogenous Proposition 98 (for state transfers to local school boards and community colleges); California PIT (personal income tax) deductibility from federal PIT is endogenous; the state budget is balanced; and all federal inter-governmental transfers are block grants.

The three main experiments were to reduce by a $1 billion static estimate the bank and corporation tax, personal income tax, and sales and use tax. Each of these was reduced in a separate base case experiment while holding the other two taxes at their current rate levels. These are the three main sources of tax revenue for the state and DRAM was developed to guide the Department of Finance in its dynamic analysis of revenue policy change. Further, changing each of these exposes DRAM's functional forms and parameters to significant exogenous shocks—ideally revealing both the model's properties and the appropriateness of key elasticity parameters imposed. Public policy debate in the state and elsewhere has focused on the subject of the economic efficiency implications of tax reduction, thus tax increases were not chosen.

A second series of experiments was conducted to test the model's properties and key parameters by varying groups of elasticities and solving the model. The tax cut experiments were repeated in the face of changes in trade, labor supply, migration and investment elasticities being varied plus or minus fifty percent from levels chosen in the base case. These levels were chosen by professional judgment in the middle ground of published values.

In a third series of experiments key assumptions made when developing DRAM were altered and tested against a similar set of tax experiments. These assumptions involved the degree to which changes in California PIT affect federal PIT through itemized deductions; the choice of formulae for Proposition 98 funding of K-14 schools; the manner in which the General Fund is balanced; and the degree of interrelationship between federal matching funds for health and welfare and California's expenditures. As final elements in this third series, a set of elasticity levels and assumptions that tend to minimize the feedback effects is identified along with a set of elasticities and assumptions that tend to maximize the feedback effects.

The results of the second and third series of sensitivity analysis experiments are available in the major report (Berck *et. al.*, 1996). In the sections following, the results of the first series of experiments are reported with the aim of demonstrating the uses and properties of DRAM. The results from four particular solutions to DRAM are presented (calibration and the three tax experiments). While the equations and data that make up the model were developed carefully, readers are reminded that all economic models are abstractions from reality. The economy of California is a huge, complex and continuously evolving entity. The development of DRAM required a set of major simplifications of that entity. No claims are made that all of the detail of California is presented in the interpretation of the results from experiments conducted, nor that all economic agents will behave as represented in the equations or results of DRAM. Further, no policy recommendations are to be found in the choice of experiments made or indications for interesting avenues of future research.

Calibration

This is the first step in using an applied CGE model. The term calibration applies to a process during which the equations of the CGE are solved without making any policy change. If the model solves in such a way as to replicate its original data, calibration has been achieved. If not, errors in data or model formulation almost certainly exist. Calibration of the model is shown by comparing the 'Base' and 'Today' columns of Table 1. The degree to which DRAM has been calibrated to its data is shown to have been accomplished to beyond the fifth significant digit. This is an important first step in judging the results of a CGE, whether a simple theoretical simulation model or a large, complex applied model such as DRAM. By achieving this result, one can only claim that the equations of the model are consistent with their initial data. By itself, calibration is only the first step in a model validation program.

Bank and Corporation Tax Reduction

These results are in the 'B & C' column in Table 1 for a reduction in the B&C taxes by a $1 billion static estimate. B&C taxes are modeled as a tax on payments to capital in DRAM. Rates for these were reduced across-the-board by about 20 percent. The model solution values are for General Fund revenues to drop by $844 million and Special Fund revenues to rise by $28 million. Thus, the model indicates tax revenues for the state dropping by $816 million, generating the estimate of about 18 percent dynamic feedback effects. The solution value for the rental rate for capital is 0.4 percent lower than the initial data and the average wage is marginally higher. Employment would rise by 12,000 and investment by $47 million. All of the increase in employment is accounted for by in-migration. How are these results found, i.e. what channels of change are used in the model to find a new equilibrium in the face of a change in the B&C tax rates?

Table 1: Basic Model Experiments

	BASE	TODAY	B & C	P I T	S & U
B & C	4.801	4.801	3.830	4.804	4.807
P I T	19.490	19.490	19.567	18.478	19.505
S & U	17.448	17.448	17.497	17.460	16.486
General Fund	42.307	42.307	41.462	41.310	41.507
Special Fund	13.403	13.403	13.431	13.409	13.280
STATIC	-	-	(1.000)	(1.000)	(1.000)
Δ General Fund	-	-	(0.844)	(0.996)	(0.800)
Δ Special Fund	-	-	0.028	0.006	(0.124)
$ Dynamic	-	-	0.184	0.010	0.077
% Dynamic	-	-	18.390	1.003	7.673
Personal Inc.	772.177	772.177	773.777	771.439	772.284
Investment	67.629	67.629	67.776	67.635	67.645
Population	23.421	23.421	23.434	23.418	23.425
Wage Index	100.000	100.000	100.028	99.788	99.962
K index	100.000	100.000	99.597	100.006	100.015
L Demand	12.624	12.624	12.636	12.642	12.634
K Demand	13.526	13.526	13.674	13.532	13.542

Row	Description
B & C	Bank and corporation tax revenue ($ Billion)
P I T	Personal income tax revenue ($ Billion)
S & U	Sales and use tax revenue ($ Billion)
General Fund	General Fund Revenue ($ Billion)
Special Fund	Special Fund Revenue ($ Billion)
STATIC	The static estimate of the tax change ($ Billion)
Δ General Fund	Change in General Fund Revenue from initial conditions ($ Billion)
Δ Special Fund	Change in Special Funds Revenue from initial conditions ($ Billion)
$ Dynamic	Dynamic revenue effects ($ Billion)
% Dynamic	Dynamic revenue effects expressed in terms of the static cost (%)
Personal Inc.	Statewide Personal Income ($ Billion)
Investment	Gross Investment ($ Billion)
Population	Population of households in the state (Millions)
Wage Index	The change in the wage rate (base = 100)
K Index	The change in the return to capital (base =100)
L Demand	Labor demand (Millions)
K Demand	Capital demand ($100 Billion)

Column	Description
BASE	The initial data supplied to DRAM
TODAY	The calibration solution imposing no changes in tax rates.
B & C	Experiment reducing bank & corporation tax rates by $1 billion.
P I T	Experiment reducing personal income tax rates by $1 billion.
S & U	Experiment reducing sales and use taxes by $1 billion.

Reductions in the bank and corporation tax (B&C) indicate that producers might be expected to implement factor substitution favoring capital over labor as a first step. With reduced capital costs, firms may demand more capital and less labor until the revenue contribution of one more unit of a factor (marginal revenue product) is just equal to the cost increase of hiring another unit (marginal factor cost). Overall the cost of doing business would be reduced—or firms would not substitute factors for each other. Since DRAM embodies the assumption of perfect competition, domestic prices fall to domestic marginal costs. Exports increase and imports decrease. Domestic output rises to meet demand, but with some of the initial cost-push deflation being lost. Rising output further increases the demand for capital and labor and firms hire back more than their initial losses in staff.

Concurrently, households receive a higher percentage of available capital payments. They offer more capital to business and trade off some of their after-tax gains in lower market rental rates for capital. As increased export and domestic demand increase the demand for capital, most of the rental rate loss is regained by the owners of capital. Owners of labor gain in the overall result. Market wages rise slightly with the increased demand for labor and prices fall. Thus, real wages have risen.

While the private sector makes its investment, substitution, supply and demand decisions, the public sector experiences a drop in revenues. The initial cut in the B&C tax reduces General Fund revenues by $1 billion. To balance the budget, DRAM first allocates funds transferred to local education on the basis of changes in per capita General Fund revenues—which have now fallen. The remaining portion is modeled as a reduction in California's transfers to local governments in aid of health and welfare expenditures, both transfer payments to individuals and other costs. Reduced education transfers mean fewer jobs in schools and community colleges while less purchasing is made by education authorities. The public sector loses about 5,000 jobs. This loss and reduced public demand for goods and services offset some of the expansive effects of private economic decisions.

However, as any neoclassical CGE would predict, replacing private dollars for public dollars leads to economic expansion. Two elements of DRAM would tend to guide researchers to believe that these results may be an upper bound to those expected from a B&C reduction. First, DRAM does not link the effects of reduced education expenditure on the productivity of labor for private businesses. To the extent that it would, some of the expansive effects of such a tax reduction may be lost. Second, DRAM does not incorporate the deductibility of California's B&C from federal corporate tax. To the extent that all would be deductible, the results may be overstated. However, California apportions profits by weighting sales in California equal to the weights placed on factors (assets and employees). This reduces the connection between California's production and the tax liability. Further, the vast majority of B&C is paid by companies who are subject to this apportionment formula. To the extent that the lack of deductibility matters, the DRAM results should be viewed as an upper bound—possibly overstating the impact by as much as one-sixth of the feedback shown.

However, the announcement effect of California reducing its corporate profits tax by about 20 percent may offset these cautions. To the extent that California breaks any lingering corporate perceptions that it is a 'high tax state' by significant reductions in the B&C, feedback effects could increase.

Note that the stages discussed above are not presented in the output file in the table. DRAM solves the model as a set of almost eleven hundred simultaneous non-linear equations. The results should be viewed as answering the question: what would today's economy look like if we had put into place reduced B&C tax rates five or six years ago. The two key lags exist in the real economy suggesting that five or six years are needed to see the full feedback effects come from observations in factor markets. The first impact of investment decisions today begin to be observed about ten quarters later. Full effects are usually found after about five years. Migration is somewhat slower: its full effects are generally accepted to be felt after about six years. Most, if not all, of the dynamic feedback effects demonstrated by DRAM will be found in this time frame.

Personal Income Tax Reduction

These results are shown in the 'PIT' column in Table 1 for a reduction in the PIT by a $1 billion static estimate. Rates for these were reduced across-the-board by about five percent. In the solution, General Fund revenues drop by $996 million and Special Fund revenues rise by $6 million. Thus, tax revenues for the state drop by $990 million, generating the estimate of about one percent dynamic feedback effects. The rental rate for capital rises marginally and the average pre-tax market wage falls by 0.2 percent. Employment rises by 18,000 and investment rises marginally. About a third of the increase in employment is accounted for by net in-migration. Little in the way of dynamic revenue feedback effects are found, yet significant economic changes are made.

Reductions in the PIT begin with households. Their California taxes go down, but the most significant reductions are experienced by high income households who itemize state and local taxes as deductions from income for federal tax purposes. Thus, about one quarter of the California tax reduction leaks out of the state in increased federal taxes. However, after-tax returns to work increase, except for the lowest income group – who have a marginal tax rate of zero. Labor supply increases and in-migration occurs for all but the lowest group. With some increase in labor supplied, pre-tax market wages fall in the model. Of course, in the real economy, market wages seldom fall. The model's results should be considered to reflect a slowing of wage inflation over several years – say a drop from 3.0 percent a year to 2.9 percent for a couple of years.

Faced with lower wage costs, producers can be expected to substitute labor for capital as a first step, demanding more labor and less capital until the marginal revenue product of each factor is equal to its marginal factor cost. Overall, the cost of doing business is reduced. Since DRAM assumes perfect competition, domestic prices fall to domestic marginal costs. Exports increase and imports decrease. Domestic output rises to meet demand, but with some of the initial cost-push deflation being lost. Rising output further increases the demand for capital and labor and firms begin to demand more capital, restoring investment to slightly higher than its original level. One important consequence of lower wages is that there is a softening of nominal PIT revenues due to lower nominal incomes (but higher real incomes).

As with B&C reductions, while the private sector makes its investment, substitution, supply and demand decisions, the public sector accounts experience a drop in revenues. The reductions have very similar effects. However, as any neoclassical CGE would predict, replacing private dollars for public dollars leads to economic expansion. Unlike with B&C, DRAM incorporates the deductibility of PIT in an explicit way. However, it still faces the criticism of not linking spending reductions on education and infrastructure to long-term productivity. The announcement effects would again tend to offset some of this criticism.

At first glance, the overall net feedback effects shown for PIT reductions may seem to imply that there are few, if any, gains to reducing PIT. The results are far different from such an impression. The large leakage due to deductibility for the group experiencing the largest dollar impact of the reductions and their higher savings rates (another leakage), are overcome by large feedback effects. Not much over one-half of the tax reduction enters the economy of California after these two avenues of leakage are accommodated. The state's budget is balanced by reducing expenditures by the full (dynamic) amount of the tax reduction. In spite of these forces that would tend to drag down the economic performance, private job gains outstrip public job losses by better than three to one. High income households migrate to California and the economy expands. The results from DRAM imply large real economic gains to reductions in the PIT.

Sales and Use Tax Reduction

These results are shown in the 'S & U' of Table 1 for a $1 billion tax reduction. Rates for these were reduced across-the-board by about six percent. In the solution, General Fund revenues drop by $800 million and Special Fund revenues fall by $124 million. Thus, tax revenues for the state drop by $924 million, generating the estimate of about eight percent dynamic feedback effects. The rental rate for capital rises marginally and the average wage falls marginally. Employment rises by 10,000 and investment rises marginally. Little of the increase in employment is accounted for by net in-migration. Dynamic feedback is found of a distinctly different form than either B&C or PIT tax reductions.

Feedback for S&U appears to come from two places: the sales tax on intermediate goods and reducing the cost of goods to consumers. California is one of the few states to place a sales tax on intermediate goods. These become a cost of production and California's goods bear these costs when competing in export and domestic markets. Reducing these cut production costs without making changes in the relative costs of factors of production. Given the competitive market structure, domestic prices fall and the trade balance improves. Domestic producers increase production. Households face lower costs of goods and consume more goods. This increases the demand for goods, an increased share of which goes to domestic producers.

Overall, S&U feedback effects are significant. While the reduction is small (about 6 percent of tax rates or a ½-percent rate reduction), significant positive feedback effects exist in DRAM's results. While significant, these results face the same criticisms as PIT reductions in terms of being possible overestimates due to the lack of linking productivity and infrastructure spending and possible understatements due to announcement effects. The latter criticism may be particularly significant in terms of the sales tax on intermediate goods. Being one of the few states to do so, California may receive significant gains from changes to these taxes.

Conclusions

California Department of Finance has invested considerable effort into building an analytical engine to drive its dynamic scoring of revenue proposals. The first stage of a usable model has been built, tested and exposed to academic peer review. While the model will undergo further testing, updating and review, it is now available for bill analyses purposes and for the use of other state revenue analysis functions to examine in detail for their own uses.

The results from the initial sensitivity analysis experiments are encouraging. When capital taxes are reduced, firms are expected to switch from labor to capital, reduce prices and improve the domestic balance. When income taxes are reduced, the residual after deductibility and savings are considered is sufficient to induce labor supply and migration effects sufficient to overcome the leakage. Although the revenue feedback figures for PIT reductions are small, the economic effects are large. Sales tax experiments demonstrate that the application of sales taxes to intermediate goods may be an interesting area for future research.

References

Berck, Peter and Andrew Dabalen (1995), *A CGE Model for California Tax Policy Analysis: A Review of Literature*, report to the California Department of Finance, Sacramento.

Berck, Peter, Elise Golan and Bruce Smith (1996), *Dynamic Revenue Analysis for California*, report available from the California Department of Finance, Sacramento.

Lucas, Robert E. Jr. (1976), "Econometric Policy Evaluation: A Critique," in *The Phillips Curve and Labor Markets*, K. Brunner and A. H. Meltzer (eds.), North Holland, Amsterdam.

Walras, Leon (1954), *Elements of Pure Economics, or the Theory of Social Wealth*, translated by William Jaffe, Allen and Unwin, New York.